

HARALD U. SVERDRUP

1888 - 1957

BY WALTER MUNK
AND DEBORAH DAY



■ ■ ■ The Early Years

Harald Ulrik Sverdrup came from Norway in 1936 to serve as the third director of the Scripps Institution of Oceanography. A cosmopolitan scientist, fluent in Norwegian, Swedish, Danish, English, and German, and somewhat in French¹ he had earned a reputation as a tough polar explorer.

Sverdrup was a member of a distinguished Norwegian family that was heavily involved in the Lutheran church. His father and four brothers all became ministers. Sverdrup's father was Johan Edvard Sverdrup, a conservative Lutheran pastor and theologian. Johan's first wife, Marie Vollan, died in 1891, leaving Gudrun (b. 1887) and Harald (b. 15 November 1888). Johan's second wife was Marie's sister Agnes, they had five children including Sverdrup's brothers Einar and Leif.

As a boy, Harald was interested in evolution and astronomy. His family favored the classics. Upon entering gymnasium, Sverdrup selected the classics option with emphasis on Latin rather than physics and mathematics. But then he welcomed an opportunity to return to the technical subjects by attending the Norwegian Academy of War for one year (and finishing as top man in athletics). In 1914, he passed the university examinations in physics, mathematics, chemistry, and botany, and planned to major in astronomy. When Vilhelm Bjerknes offered him one of the coveted assistantships endowed by the Carnegie Institution of Washington, Sverdrup turned to meteorology and oceanography, and he published his



Sverdrup Family, Norway, ca. 1914. Back row (L to R): Harald, Einar, Mimi, Jacob; front row: Gudrun, Edvard, Agnes, Helga.

first paper (on atmospheric inversion layers). His association with the Carnegie Institution was to play a crucial role in Sverdrup's appointment to the Scripps directorship. In 1914 Bjerknes was offered a professorship at the University of Leipzig, and he took Sverdrup with him. It was there during the war years (and experiencing hunger) that Sverdrup wrote *Der Nordatlantische Passat* (North Atlantic Trade Winds), for which he was granted a degree from the University of Oslo in 1917.

Sverdrup could have fallen into a comfortable and respected university career, but instead he accepted the offer by Roald Amundsen to take charge of the scientific work on the North Polar *Maud* expedition. In his words:²

I felt that since I had spent many years partly in theoretical work, partly in the discussion of observations, which had been collected by others, it would be extremely valuable for me to spend a number of years in close contact with the events in nature and with the opportunity to get fully acquainted with various techniques of observation.

To these words, he added by hand: "And I did not mind the adventure."

The expedition left Norway in July 1918, and was expected to return in three or four years. It did not return until December 1925. The expedition carried out an intense program of observations, the analysis of which occupied Sverdrup up to 1933.

There were a number of important interruptions.

- In 1928 he married Gudrun Bronn Vaumund and adopted her daughter Anna Margrethe.
- In 1929 he signed up with Fridtjof Nansen to take the *Graf Zeppelin* across the North Pole.
- In 1930 he spent half a year at the Carnegie Institution in Washington for analysis and discussion of the oceanographic observations taken on the last cruise of *Carnegie*.
- In 1931 he participated in the Lincoln Ellsworth North Polar Submarine Expedition, again as leader of the scientific work.
- In 1934 he spent eight weeks on the high-lying snow fields of Spitzbergen with glaciologist Hans Ahlmann.

Although *Maud* never came close to the pole, *Graf Zeppelin* did not fly, and the submarine did not dive, Sverdrup somehow managed to improvise, turning all these disappointments into positive experiences. He did this by taking advantage of every opportunity for careful observations followed by analysis and synthesis. Improvising is a way of life for oceanographers.

The *Maud* Expedition. The *Maud* Expedition epitomizes Sverdrup's approach, discipline, and scientific style. In 1918, with World War I still raging, a twenty-nine year old Sverdrup took charge of the scientific work (with additional duties as navigator and cook) aboard *Maud* on Amundsen's North Polar Expedition. At the turn of the century, Nansen had conducted his famous drift aboard *Fram*. From the measurements taken and a brilliant subsequent analysis, Nansen had concluded that there was no land in the central Arctic, and that the currents entering and leaving the Arctic played a major role in climate.

This was not accepted at the time. Amundsen's project provided the opportunity to test these unpopular notions. To family friends who opposed his plans, Sverdrup wrote "... I was not cut out to be a theoretician. And not the least, if I am able to make a little scientific contribution, then it will be a contribution to Norwegian science."³

Two years later, unable to break into the ice pack, *Maud* entered the port at Nome, Alaska, to take on fresh supplies. One year later she had to pull into Seattle to repair a broken propeller. Much has been said about the frustrations encountered on the expedition, and too little about the valuable work that was done: on tides, currents, physical properties of seawater, sea ice, marine geology, aurora, gravity, magnetism, atmospheric electricity, astronomic observations, and the animal and bird life in the drift ice.



Harald Sverdrup, just behind the white dog, aboard R/V *Maud*, ca. 1921.

Sverdrup used every interruption to push his work forward. During the port calls in Alaska, Amundsen allowed participants to leave the expedition, and some did. Sverdrup admits to being tempted, but decided to fulfill his obligation, in spite of the immense difficulty in carrying out the observational program. "These years were really valuable because they brought me in the closest possible contact with nature, a circumstance which to one who works in geophysics cannot be overestimated."⁴

The most significant of the *Maud* papers, *Dynamics of Tides on the North Siberian Shelf*, was completed on shipboard (oceanographers will appreciate this feat).

These were the formative years of Sverdrup's scientific career; he developed a first-hand appreciation of the interdependence of elements of the ocean environment. The Arctic years also formed the basis of developing his personal qualities, particularly a high degree of self-discipline. Amundsen, a world figure, was vain, opinionated, and not well informed on scientific issues. The relationship between the expedition leader and the chief scientist was not an easy one. But Sverdrup made it work. Years later he wrote, "the thing I am most proud of was that after years ... we departed as friends." He thanked Amundsen "not just because you provided me with a wonderful opportunity to work with things that interest me, but even more because you helped make a man of me."⁵

Sverdrup is Called to America. In 1930, while spending half a year at the Carnegie Institution in Washington, Sverdrup was approached by Carnegie President John C.

Merriam and offered the initial directorship of the Woods Hole Oceanographic Institution.⁶ Sverdrup turned down the offer because he needed more time to complete the *Maud* work.

In 1935 Bjørn Helland-Hansen, returning from a visit to the United States, asked Sverdrup whether he would consider taking the directorship of the Scripps Institution of Oceanography for a limited number of years. Sverdrup accepted the position for a period of three years, later extended to five. Then war broke out, and it was to be twelve years before he returned to Norway.

Sverdrup Comes to Scripps. Sverdrup found an institution without seagoing facilities and without seagoing oceanographers. There was no underlying research theme, no credible teaching program. When Sverdrup accepted the position, he wrote Robert Gordon Sproul, President of the University of California, that he intended to make the institution live up to its new name by taking it to sea.⁷ Sverdrup had brought two current meters with him from Norway, and he hit the ground running.⁸

The staff had learned only four months earlier that Sverdrup was coming,⁹ and some viewed the appointment with apprehension. During the era when Scripps was a "marine observatory,"¹⁰ Ritter had appointed a series of "collectors." For example, Percy Barnhart curated specimens, Stanley Chambers wound the mechanical devices at the end of the pier that measured tide and temperature, and other staff recorded data daily in big bound volumes. What role did they have in an institution focused on offshore rather than coastal research? These men had more to fear than the loss of their salaries, for their families lived in little cottages rented from the university at very moderate rates.

On the other hand, staff members already working on biological oceanography were pleased.¹¹ Professor W. E. Allen welcomed the appointment of Sverdrup,¹²

This seems to indicate a definite commitment to oceanography. I understand that the new Director is to get here about Aug. 25. The Bacteriologist, Dr. C. E. ZoBell, has been appointed Assistant Director with the duty of trying to organize or harmonize the biological work. Dr. Sumner has been greatly upset by the changes but seems to be unable to do anything about it. The institution may get down to some real oceanic work after all.

■ Scripps Goes to Sea

Sverdrup had a very direct style. He reorganized weekly faculty meetings into research seminars on specific themes. Minutes were taken recording the remarks of each faculty member by name. At one of his first faculty meetings in 1936, Sverdrup asked each staff member for his opinion "on the value of a ship to your particular research."¹³ This was a loaded question. The institution owned only one vessel, a sixty-four foot purse seiner named *Scripps*, which was capable of only short coastal day cruises. Shortly after Sverdrup's arrival, this ship exploded and burned at anchor at the San Diego Yacht Club.¹⁴ Sverdrup turned to Robert Paine Scripps, the heir to the estate both of his father, E. W. Scripps and his aunt, Ellen Browning Scripps.

Bob Scripps was well prepared for his first meeting with Sverdrup. He had a copy of Helland-Hansen's 1935 report recommending Sverdrup for the directorship, and he was

privity to the negotiations that brought Sverdrup to La Jolla. In his report, Helland-Hansen mentioned the inadequacies of *Scripps* and pointed out the need for a ship of substantial size, capable of undertaking a dynamical survey of the North Pacific.¹⁵ Scripps had offered his yacht *Novia del Mar* for the occasional use of the institution, and by March 1937, he had agreed to finance the purchase and reconditioning of a new ship for the Scripps Institution. He already had an eye on the former yacht of actor Lewis Stone.¹⁶

When *E. W. Scripps* was ready for sea, Sverdrup organized a cruise to Guadalupe Island and two expeditions to the Gulf of California. However, he decided to focus on repeated visits to a limited ocean area similar to Henry Bigelow's work in the Gulf of Maine rather than traditional wide-ranging scattered deep-sea expeditions. This was consistent with his conviction that the Scripps program should ask well-posed significant questions and make the observations to answer those questions.

The Marine Life Research (MLR) program, which was initially proposed in 1939,¹⁷ and which continues to this day, fell in perfectly with Sverdrup's plans and gave the institution scientists an opportunity to begin intensive work in a clearly defined and important area off the California coast. The resulting departure from the traditional expedition era to properly sampled time series is a benchmark in the history of ocean science.

Scripps faculty and staff who did not go to sea felt themselves at a disadvantage. Funds continued to be scarce, and Sverdrup allocated his meager resources to work at sea. He tried to bring chemical and physical oceanography up to par with biological oceanography/marine biology. As there were no new faculty or staff billets and no new funds, this change was a painful one.

Sverdrup quietly made some staff changes. George McEwen had been issuing yearly climate predictions for San Diego. Sverdrup asked McEwen to discontinue this practice; he perceived (and we now know) that the predictions were without skill.¹⁸ Under McEwen's supervision, refugee Polish climatologist Wladyslaw Gorczynski¹⁹ was building a little fiefdom for computing a climatological constant (suitably labeled "G") that combined temperature, rainfall, sunshine, and other local statistics into a single number. It was normalized to $G=100$ for San Diego, and was less than 100 for all other communities (thus enjoying a popularity among local officials). Sverdrup put an end to this. Sverdrup took a research position from biologist Easter Cupp and gave it to phycologist Marston Sargent. He regretfully let chemist Erik Moberg go when alcohol got the better of him, and recruited Carl Hubbs from the University of Michigan at Francis Sumner's retirement. Richard Fleming and Roger Revelle, both with newly minted doctorates, found themselves with unparalleled opportunities for research at sea because the older faculty were unwilling or unprepared for sea duty. The faculty who did not go to sea felt fiscally beached.



R/V *E. W. Scripps* under sail at Scripps Institution of Oceanography, ca. 1937.

Two of the younger faculty whose work was in the laboratory, biochemist Denis Fox and bacteriologist Claude ZoBell, were concerned about the increased focus on seagoing activities. ZoBell was used to working independently and did not distinguish between seagoing and laboratory scientists at Scripps.²⁰

While it has been the policy of the institution to allow the staff members a high degree of freedom in the selection of problems for investigation, it has been the common objective of all to contribute to the science of the sea and its relation to man.

As Assistant Director, ZoBell had assumed quite a bit of administrative responsibility toward the end of Vaughan's term as director, but he acknowledged Sverdrup's leadership.²¹

Fox wrote Sverdrup that after three hours of discussion, the faculty could not agree on the definition of "oceanography" and suggested that the term "marine science" be used instead.²² Fox was fussy about titles and wrote lengthy memoranda to the director on the lack of proper institution stationery and the unsightly defecation of seabirds on university grounds. He felt slighted when the young postdocs Fleming and Revelle were given plum assignments. Both Fox and ZoBell had been proposed for promotion to Assistant Professor in 1933, but this was delayed until 1936 because of the Depression. Sverdrup recommended their promotion to Associate Professor in 1938, but this was denied until 1942! Both men believed that the delays were unjust.

Money was always a problem. Ten years before the Office of Naval Research was to become the catalyst of ocean research, Sverdrup contemplated going to the Navy for support, but concluded, "The Navy, when you get right down to it, doesn't care about oceanographic research."²³

Teaching Oceanography. Sverdrup began reforming the curriculum of Scripps as soon as he arrived on campus. The institution was not empowered to grant degrees. During the Sverdrup years, degrees for graduate work at Scripps were granted by UCLA. Sverdrup worked closely with a select faculty committee that included Claude ZoBell to outline a new syllabus in time for publication in the University Catalog. In 1938, Sverdrup began working on a textbook, *The Oceans*, with two co-authors from the Scripps staff, Richard Fleming and Martin Johnson. Even before it was published, chapters were used to shape the course in oceanography at Scripps. The entire faculty was organized to teach a comprehensive series of lectures, that covered biological, chemical, geological, and physical oceanography. Claude ZoBell felt that physiology of marine organisms was not sufficiently represented in the curriculum. In Sverdrup's view oceanography was not synonymous with marine science. Francis Sumner felt that scientists should be free to follow wherever their research led them and therefore disagreed with the concept of an organized program. Sverdrup listened to the opinion of his faculty, but then held his course.

It is interesting to contrast Sverdrup's views with those of Ritter. Ritter wanted physical oceanography to serve the interests of biologists. Sverdrup wanted broad cooperative interdisciplinary studies. "I wish to underline the necessity of broad training," Sverdrup wrote:

Every oceanographer, regardless of how narrow his specialty may be, should have some basic knowledge of the fields of all the marine sciences, partly because he ought to be acquainted with the terminology of his fellow workers and partly because he should be able to recognize results within his own field which have a bearing on problems of others or to know where he may obtain information that has a bearing on his own.²⁴

Sverdrup's goal was to train oceanographers through a rigorous academic program, but he always emphasized the importance of experience in the field:

Much as I respect the theoretical and laboratory physicists and chemists, it has frequently struck me that these have a tendency to identify conditions in nature with such which can be reproduced in the laboratory. They often lack an appreciation of the complexity of the atmosphere and the ocean and the physics of the earth—and many of those I have met have little knowledge of how far we have advanced in our understanding of the phenomena encountered. I have repeat(ed)ly seen physicists embark on programs of observation without knowledge of what had been accomplished.²⁵

Sverdrup did not believe that atmospheric science should be part of the curriculum of the Scripps Institution in 1936. This was certainly a departure from the Bergen School model. There were several reasons for his views. First, Scripps's Depression Era budget was not adequate to support an expansion into atmospheric science. Second, Sverdrup knew from his frequent trips to UCLA and his interactions with Vern Knudsen and Joseph Kaplan that the UCLA Department of Physics was interested in expanding in geophysics.²⁶ In fact, Sverdrup helped UCLA recruit his Norwegian colleagues Jacob Bjerknes and Jorgen Holmboe in 1940 to provide the nucleus for a Department of Meteorology. Atmospheric science would thus have a home at UCLA, and there would be fertile opportunities for oceanographers from La Jolla to interact with geophysicists from Los Angeles.

Sverdrup tried to bring the Scripps Institution of Oceanography in line with the academic policies of the rest of the University of California. Before the Sverdrup years, students at Scripps were attached to and dependent upon individual faculty members, who



Detail, Group Portrait, Scripps Institution of Oceanography, 1939. Standing (L to R): Stanley Chambers, Ruth Ragan, Peter Doudoroff, Erik Moberg, Harald Sverdrup, Richard Fleming, Tillie Genter, Helen Steward, Yale Mintz, Denis Fox. Seated: Bob Durant, Claude ZoBell, Marston Sargent.

were empowered to shape and control their graduate work. Sverdrup centralized procedures for admitting and supervising graduate students. Students from other departments could enroll in Scripps courses, and Sverdrup even approved the enrollment of university undergraduates in single courses under certain conditions. However, he required that all graduate students enrolled in oceanography complete the core curriculum before they focused on a particular sub-discipline within oceanography. The faculty at Scripps and elsewhere lauded these reforms.²⁷ One effect of this change was to diminish the power of the individual faculty advisor. Sverdrup, as chairman of the Department of Oceanography, had the sole power to accept or reject prospective students.

Sverdrup emphasized research before the educational program of the Scripps Institution. His first priority was always to take the institution to sea. The training of oceanographers, for whom at the time there were no fellowships and little prospect of employment, was secondary. Nevertheless, he did accept some doctoral students. Walter Munk, from the California Institute of Technology, became Sverdrup's student in 1940.

The Ocean Bible. Amidst all the challenges of, and to, the institution, Sverdrup continued his personal research. He devoted much effort with Martin Johnson and Richard Fleming to *The Oceans: Their Physics, Chemistry and Marine Biology*, known informally as "The Bible" (this is the closest he came to living up to the Sverdrup family church tradition). *The Oceans* is the last comprehensive work treating all aspects of oceanography between two covers; it reflects Sverdrup's broad exposure during his seven years in the Arctic.

The Oceans is such a landmark accomplishment for Sverdrup and the Scripps Institution that one should take a closer look at how it came about. In the spring of 1937, Sverdrup and Caltech's Robert Millikan discussed the need for a textbook in oceanography to replace the outdated volume in the National Research Council's *Physics of Earth* series.²⁸ Prentice Hall college textbook editor D. A. Tacke wrote Harald Sverdrup 21 December 1937 at the recommendation of Theodore von Kármán to ask if he would write the text.²⁹ Sverdrup's secretary Ruth Ragan recalled that Sverdrup was about to turn it down, but then decided to do the book.³⁰ By the summer of 1938, Sverdrup had selected his two co-authors, and by October, they had an outline. *The Oceans*, Sverdrup's vision of oceanography, represents what he was trying to accomplish at the institution and what he was trying to build into the curriculum.³¹

Chapter XV, "The Water Masses and Currents of the Oceans" has survived the fifty years since its publication.³² Sverdrup was working on this chapter during the summer of 1940. His office had a small back door to a room occupied by his graduate student, Walter Munk. Sverdrup would appear at Munk's door and say quietly, "Come and listen." In the middle of the director's office a big wooden table was piled high with books and papers in stacks corresponding to major ocean basins. Sverdrup would walk slowly around the table, pick up selected papers, and speak on what he thought were the essential features. He would go through this exercise many times following different guidelines. It was at one of these sessions that he decided to organize the chapter around the Antarctic Ocean, looking at the Atlantic, Pacific and Indian Oceans as northward pointing fingers. When he was ready, he would call in Miss Ragan and dictate a section of the chapter without referring to notes.

Occasionally, Sverdrup would have Munk read off numbers for him to plot (today's computer-generated plots miss the excitement of wondering where the next point will fall). Sverdrup would beam if a point confirmed a developing pattern and scowl if it missed. Each point was taken seriously, and outliers were often rationalized. The procedure was consistent with the motto in the preface:

... we have preferred definite statement to mere enumeration of uncorrelated observations and conflicting interpretations, believing the treatment selected would be more stimulating.

All of Sverdrup's writings were guided by observational material. Mathematics was used as a concise *a posteriori* discipline for organizing his thoughts, not as a means of deriving new insights.

The arrival in La Jolla of the first printed copies of *The Oceans* on 19 December 1942 was celebrated at the Sverdrup house. Miss Ragan was temperate, and this was to be the first (and last) time that her lips touched wine. The publication in the United States was followed by an unprecedented delay in distribution overseas. G. A. Morriss of Prentice-Hall wrote Sverdrup, "the Navy Department has just phoned me that it would be of great aid to the enemy should (*The Oceans*) fall into their hands."³³ The book did not become available abroad until VE Day in May 1945. By then a copy had been hand-carried to England by the hydrographer, Vice Admiral Sir John Edgell and was reviewed by J. N. Carruthers.³⁴

■ ■ ■ The War Years

In April 1940, Norway was invaded by the Nazis. The Norwegian King, Haakon VII, fled and established a Free Norwegian government in exile. The occupation of Norway was a traumatic experience for the Sverdrup family. They responded forcefully. Anna became a lieutenant in the U.S. Army Nurse Corps, and Gudrun was active as a nurse's aide and Red Cross worker. Sverdrup's brother Leif, a U.S. citizen, was a major general in the Army Corps of Engineers and served as Chief of Engineers in the Pacific Theater of



Walter Munk and Harald Sverdrup, Scripps Institution of Oceanography, 1940.



Richard Fleming, Harald Sverdrup, and Walter Munk watch Ruth Ragan type *The Oceans*. Cartoon by Martin Johnson.

War under General Douglas MacArthur.³⁵ Harald Sverdrup felt that he had two choices: return to Norway as "another old man with a gun" or stay in America. On 1 May he wrote to President Sproul requesting that his temporary appointment as director become permanent.³⁶

... Recent developments have changed all of my plans for the future. I wish now to remain with the University of California, hoping that there are no objections to changing the present temporary arrangement to a permanent one. I am taking this step without having consulted Helland-Hansen, but I am convinced that he will have no objections. Regardless of what happens in the near future, and regardless of the ultimate outcome of the war, Norway will be economically ruined and will have to face a long period of reconstruction. Scientific activity will suffer because all efforts will have to be concentrated upon providing the needs of daily life. My ability and training are not of such nature that I can hope to render active help during such a period. ... In view of these circumstances I feel that my place is here where I may hope to contribute my share toward the further development of research activities. I wish to add that, having the misfortune to be away from Norway during the last crucial weeks and the worse time to come, my family and myself could not have found ourselves in better surroundings. We could not have found greater sympathy and greater friendliness, and I could not have found more absorbing and interesting work. ...

On 11 June 1940 Sverdrup, his wife Gudrun and daughter Anna applied for U.S. citizenship, and were naturalized in 1944.

The University of California, its eye on the unstable world political situation, created a new laboratory at Point Loma in San Diego, close to naval and dockyard facilities, called the San Diego Laboratory and eventually renamed the University of California Division of War Research (UCDWR). *E. W. Scripps* was conscripted by the Navy for use at the UCDWR.

Sverdrup had spent a lot of time commuting to UCLA. This slackened off in 1940, permitting him to participate increasingly in the Point Loma program.³⁷ The wartime work of Scripps Institution would be increasingly focused at Point Loma. In July 1941 Sverdrup took over as head of the UCDWR oceanographic division, with emphasis on submarine detection. Here ocean processes play a crucial role; the discovery of the "skip distance," the explanation of the "afternoon effect" (surface warming providing a near-surface shadow zone), the association of the deep scattering layer with the diurnal migration of copepods, etc. gave Sverdrup a much desired opportunity to be part of the battle against the German invaders. Japanese bombing of Pearl Harbor in December 1941 precipitously enhanced the sense of urgency. On the first of March 1942 Sverdrup was suddenly denied access to the Navy laboratory.

It was to be another fifty years until we learned what had happened, as revealed in papers released under the Freedom of Information Act.³⁸ Several members of the Scripps Institution raised concerns about Sverdrup's loyalty with the FBI and the Navy Department. The abrupt denial of Navy clearance for the work at Point Loma was extremely painful to

disparate dataset into an operational procedure.⁴⁰ Sverdrup had the international recognition and prestige to persuade the Allied leadership that such prediction could be relied on.⁴¹

The Air Force invited Sverdrup to Washington. He responded immediately and spent most of October working with Munk at the Pentagon. Unbeknown to them, they were under twenty-four hour surveillance. At the end of October the method for wave prediction was ready. On 8 November Allied troops landed in northwest Africa. We do not know what role the wave prediction rules played, but the wave conditions on 8-10 November were unusually favorable and the landings were successful.

Four days later the *ad hoc* employment of both Sverdrup and Munk was terminated by the Army Air Force (in Munk's case "terminated with prejudice"). The following January the War Department again reviewed their clearances (at the request of Commander Roger Revelle) and withdrew restrictions to their employment.⁴²

Returning to La Jolla in February 1943, Sverdrup organized a training course on weather and wave prediction. The course was modified in "real time" to incorporate the latest research results. Robert Arthur and Munk participated in teaching the courses. Over two hundred officers from the Air Force, Army, Navy, and Marine Corps received the training. These officers participated in the planning and execution of all landings in the Pacific theatre of war, including Iwo Jima, Okinawa, and the Philippines, and subsequently in the landings at Sicily and in Normandy.

The ongoing development of surf prediction methods in La Jolla coincided with planning for the Allied invasion of Europe. Responsibility for forecasts in support of OVERLORD was assigned to a complex organization comprised of three commands, including British and American meteorologists. Two very young American officers trained in the Sverdrup-Munk method, John C. Crowell and Charles C. Bates participated. Historian Sverre Petterssen recalled:⁴³

Since naval requirements would loom large in the vital operation of landings and supplying the assault forces on the coast of France, I took it for granted that meteorologists from the Royal Navy would be assigned to the team. Professors Walter Munk and Harald Sverdrup ... had developed methods of forecasting swell and surf with the aid of meteorological charts. These new techniques had been tested by the (Royal) Naval Meteorological Service and adapted for their special needs. As far as I knew, no one else had real competence in forecasting the state of the sea in the Channel and the surf on the French beaches.

A severe storm was blowing on 5 June 1944, the original D-Day and the landings were postponed. For the following day, the conditions were correctly predicted to be "unfavorable, but not impossible." The decision to proceed, rather than wait for the next favorable tidal cycle, was made at the highest Allied command level. Petterssen noted:⁴⁴

The weather, sea, and surf that caused the postponement (from June 5 to June 6) to be made, as well as the break that made the launching possible on June 6, were predicted sufficiently early to enable the supreme commander to make his decision

and issue orders that made it possible (though only barely so) to make full use of the break.

The Sverdrup-Munk method of wave prediction was declassified in November 1945 and published in two adjoining papers.⁴⁵ The published procedures are crude even by the standards of 1946 and totally inadequate today. In his book on wind waves, Blair Kinsman writes:⁴⁶

I am sure they (Sverdrup and Munk) were aware of the inadequacies of what they did ... (but) as evidence of the discharge of their moral obligation there are some thousands of World War II veterans alive today who would have been dead in the surf had Sverdrup and Munk not done their best with what they had.

Back at Scripps, Sverdrup took personal charge of a Navy-supported project to attack various oceanographic problems. This included wind and wave statistics, and the preparation of the silken "pocket handkerchiefs" to assist downed flyers in the western Pacific to navigate toward islands. The waterproof cloth charts were distributed to airmen at the beginning of each mission and stuffed in a pocket or tied around the neck. The charts were rated "confidential" but contained no classified information. We have since become keenly aware of the mesoscale variability of ocean currents (the ocean "weather") and are less confident in the usefulness of mean circulation charts.

Although the objections to Sverdrup's employment had been withdrawn, he was not granted full access to classified material. His participation involved the analysis of Navy data files and other second-hand observations, but not the intimate first-hand involvement, which is the hallmark of Sverdrup's entire career. In Munk's case, however, this led to a reversal from "terminated with prejudice" to a life-long association with Navy problems and an appointment as "Secretary of the Navy Chair in Oceanography."

NOTE: THIS IS AMONG THE VERY FIRST WAVE FORECASTS USING THE SVERDRUP-MUNK OCEAN SWELL GRAPHS
Sverdrup-Munk
FORM FOR FORECASTING SEA SWELL

May, 1943

STATION	DATE <i>Nov. 8, 1931</i>		TIME
Area of Forecast	Casablanca, Morocco breakwater		Period of Forecast
Explanation of Terms V-Wind velocity in generating area. F-Fetch. td-Duration of wind. Ho-Height of waves in generating area. D-Distance of decay. H-Height of swell. t-Travel time of swell. T-Period of swell. C-Velocity of swell at arrival. L-Wave length of swell.	Description of Generating Area(s) <i>Strong wind N of Agnes Reef which protects coast. Vel. of wave generated in high wind comes into calmer zone & does not decay as rapidly. From field right onto coast & comes down & then over behind front.</i>		
Terms	Values		Date of Arrival
V(m.p.s.)	17	12	
F(km)	1000 (behind breakwater)	2000	<i>Nov. 11, 1931</i>
td(hrs.)	16	24	
Ho(m.)	560	360	
D(km)	2200	1200	
H(m.)	180	160	
t(hrs.)	FO	61	
T(sec.)	12.5	8.5	Time of Arrival <i>2.300</i>
C(m.p.s.)			
L(m.)			

Previous Forecasts Falling Within Same Period

Date of arrival	Date of arrival	Date of arrival
Time of arrival	Time of arrival	Time of arrival
Height	Height	Height

FORECAST

Begin behind front about exactly the 24 hrs. ago, so wind 16 hrs

Charles C. Bates 2nd Lt.
Signature of Forecaster Rank

Sample "hindcast" form for the weather and wave prediction class of two hundred military officers that convened at Scripps from 20 May to 3 August 1943. The November 1942 Casablanca landings served as a model for this exercise. Officers in this class provided the operational wave forecasts for subsequent landings in the Pacific and European theaters of war. (courtesy Charles C. Bates)

■ The Postwar Years

By 1943, Sverdrup began writing a postwar research plan for the Scripps Institution. He expected postwar research funds from the Navy Hydrographic Office would support basic oceanographic research after the war, and he conferred with Roger Revelle on how Scripps should grow:⁴⁷

(Navy supported research) must be formulated such that on the one hand necessary Navy security is not impaired, on the other hand the research oceanographic institutions can be carried out with full freedom of publication.

He saw that the programs to train oceanographers would have to be expanded and felt that Scripps could make a significant contribution in this effort. The wartime experience in training Navy and Air Force weather officers would serve as a forerunner to an integrated graduate program.

This evolution meant enlarging the faculty as soon as the younger oceanographers were released from military service, expanding facilities on campus, and building a fleet. Scripps's only ship, R/V *E. W. Scripps* was returned to the institution after the war, but it was no longer an adequate oceanographic research vessel. There seemed to be two options for obtaining additional vessels. Sverdrup asked Revelle to obtain mothballed government-owned vessels. And he turned to CalCOFI, which was amassing a fleet of agency vessels for work off the California coast.

CalCOFI. In 1938, fishing industry representative Julian Burnette contacted Harald Sverdrup to express his concern about the depletion of the sardine from California waters. Over the next ten years, Burnette persuaded Governor Earl Warren and the California Legislature to levy a tax on fish landings and establish a Marine Research Committee to oversee a scientific investigation of the problem. In 1946 and 1947 fishing industry representatives reached out to scientists in California to plan a research program. Sverdrup was involved in planning the California Cooperative Oceanic Fisheries Investigations (CalCOFI), clearly modeled on International Council for the Exploration of the Sea (ICES) studies in the North Sea. The California Legislature provided \$300,000 to establish the Marine Life Research Group (MLRG) at Scripps, a sum close to the ongoing Navy support. MLRG was to oversee CalCOFI, which had the ships and the money for regular cruises to build a time series of oceanographic data. Sverdrup allocated R/V *E. W. Scripps* for use in CalCOFI cruises, and Scripps scientists were invited to participate in cruises on other CalCOFI vessels.

The pace of immediate postwar expansion at Scripps was remarkable. While UCDWR closed at the end of the war, some of its contracts became the nucleus for the Marine Physical Laboratory (MPL), established in May 1946. MPL became part of Scripps just as Sverdrup left in 1948. The whole university was growing, and Sverdrup found it more difficult to get administrative action from Berkeley in 1946 than it had been in 1936. After participating for three years in the formation of the Institution of Geophysics at UCLA, Sverdrup declined an invitation to be its first director.

The Succession. At a Scripps luncheon on 30 January 1947, Sverdrup announced that he intended to leave the institution. He favored Roger Revelle as his successor. Their mutual respect and friendship began in 1936 when Revelle spent his postdoctoral year at the Geophysical Institute in Bergen, Norway, working under the Arctic explorer Bjørn Helland-Hansen. Revelle had been a leader in the early steps toward building a seagoing component at Scripps in the prewar years. He had stood by Sverdrup in the loyalty investigation, and he then persisted to secure him a limited clearance, which made it possible for Sverdrup to operate in the postwar years. Sverdrup turned to Revelle to manage the CalCOFI program. In Revelle's words:⁴⁸

Sverdrup's support for me as his successor is also based upon the fact that I am practically the only person available who has had extensive experience at sea, in particular in the organization and carrying out of expeditions. He feels that Scripps must be, at least in part, re-oriented toward work on the high seas rather than the inshore and laboratory type of research ...



Portrait of Harald Sverdrup by Paul Williams, ca. 1946.

But opposition quickly materialized and this postponed Revelle's appointment until July 1951. The opposition was based on a preference by some for a biologist as director, but took the form of criticism of Revelle's work habits, and Revelle himself acknowledged:⁴⁹

My obvious and numerous weaknesses, such as a tendency to procrastinate, to take on too many obligations, not to delegate authority, and to be high-handed ...

Claude ZoBell, who was in Europe, wrote to President Sproul expressing his opposition to Revelle. Denis Fox formed an *ad hoc* committee including Carl Hubbs⁵⁰ and Francis Shepard that took a straw poll of candidates. Sverdrup rebuked them when they blackballed Revelle.

I believe that you have placed yourselves in a very weak position because of the procedure you have followed in expressing your views ... because blackballing of candidates without statement of reason gives no clue as to the true opinion of the voters. It is a procedure, which leaves a bad taste in the mouth ...⁵¹

In a letter to the official university Search Committee chair Vern Knudsen, Hubbs noted:⁵²

During the war, for urgent reasons, research in physical oceanography was greatly expanded. Now, with a major part of the support forthcoming for work bearing on fisheries, there will be a swing toward the biological side.

But the Scripps *ad hoc* committee was fulsome in its praise of Sverdrup:⁵³

Scripps Institution, thanks particularly to Dr. Sverdrup's able leadership, now ranks high as a research and training center in oceanography, and by oceanography we mean the balanced ensemble of marine sciences. This position should be maintained, secured and expanded, and with proper leadership and support can be.

They praised Sverdrup and denigrated Revelle, and Revelle called their bluff:⁵⁴

The point of all this is that I think every effort should be made, no trail should be unexplored, no stone be left unturned, in trying to get him to reverse his decision to go back to Norway. I have the feeling he might be persuaded if some arrangement could be made which would not let the Norwegians down too much. Professor Kaplan at UCLA is brooding about this same business and I hope others are too. Why don't you do something?

With all of this maneuvering going on, Sverdrup continued his own research.

Sverdrup Dynamics. Perhaps the most far-reaching contribution to meteorology and oceanography is the law of geostrophy: currents (winds) do not go "downhill" but move parallel to the pressure contours, at a rate inversely proportion to sine of latitude. "Sverdrup Dynamics" replaced the related balance of *forces* (pressure gradient versus Coriolis acceleration) by a balance of *torques* (wind curl versus "Coriolis (or planetary) vorticity").⁵⁵ The torque approach eliminates the equatorial infinity, but leads to a singularity at the western ocean boundaries. At about the same time Henry Stommel⁵⁶ produced his famous solution of the western boundary intensification (an interpretation of western boundary currents such as the Gulf Stream). Neither paper refers to the other, though they can be shown to be the asymptotic cases of a general solution to the wind-driven ocean circulation.⁵⁷ It is remarkable that Sverdrup derived what is now known as Sverdrup Dynamics not by mathematical manipulation (which is easy enough) but by analysis of observations, his trademark. Curiously the associated western boundary intensification was initially derived by Stommel not by analysis, but by noting the simple behavior of numerical computations.

A lot had been accomplished in Sverdrup's personal research, from the unifying thesis of *The Oceans* "Bible" to the dynamics of the equatorial circulation. But the most important contribution that he left behind was his insistence on a first-hand familiarity with

observations and their uncertainties as a basis for subsequent analysis and synthesis. This was a forerunner to the modern practice of objective mapping.⁵⁸

The Sverdrup California Legacy. Sverdrup summarized his experiences at Scripps in a Charter Day lecture in 1947.⁵⁹

Occasionally one can get very discouraged and there are times when one needs a great deal of faith and optimism in order to keep on plodding with Ritter's program in mind. It is so very tempting to follow the road of least resistance, to let the station deteriorate into a marine biological shore station, the work of which can be based on collections above the lowest low tide and on studies in the laboratory.

During the years just before the war, we made a conscious effort to push the work out to sea, but since we were cut off from undertaking any work at sea during the many years of war, we have now to develop that program again nearly from scratch, and we have again to make a large part of the activity at this institution truly oceanographic.

It was Roger Revelle, not Harald Sverdrup, who would take Scripps to sea again after the war.

Twelve years prior, Sverdrup had found an institution without seagoing facilities and without seagoing oceanographers. There was no teaching program, no underlying research theme. When he left in 1948, Scripps had three vessels, a kernel of seagoing scientists (to be greatly expanded under Revelle), an on-going program for monitoring the waters off California, and a coordinated curriculum in oceanography—the first in the United States. The academic staff had grown from six (with Sumner the only member of the National Academy of Sciences) to ten, four of whom were later elected to the academy. Sverdrup bequeathed an institution with an international reputation.

■ Sverdrup Returns to Norway

On 30 January 1947, Sverdrup announced that he would step down as Scripps Director in one year and return to Norway. After the decision was announced, the entire faculty and staff wrote Sverdrup praising "the character of the research, the quality of the instruction and the practical application of various marine sciences" during the years of his directorship, and asking him to reconsider his decision.⁶⁰ It was not an easy decision. Harald and Gudrun Sverdrup (she in particular) were homesick. They missed the change of seasons. Moreover, in the spring of 1946 Sverdrup had been asked by the Norwegian government to take the directorship of the Norwegian Polar Institute.⁶¹

At the time of this writing I expect to leave the SIO in a few weeks and to tackle a new job, hoping that I am not too old to make the change ... I hope that because of my many connections in many countries, including the Soviet Union, I may be able to do more in that particular international field from a small country like Norway than can be done from most other countries. ... It will be a particular

pleasure for me if in the future a number of American students might find it of advantage to come to Norway for special training. Also I cannot help but feel that having spent by far the greater part of my life in Norway I should like to assist in work of importance to that small nation during a period when it is struggling to get back on its feet after five years of oppression.⁶²

Yet six years previously, a month after Norway was invaded, Sverdrup had written to President Sproul requesting that his appointment as Scripps Director be made permanent.⁶³

I assumed at that time that my permanent place in the future would be with the University of California. Consequently I took steps to become an American citizen and was naturalized in 1944. I should have remained here happily ...

We will never know all the factors leading to the decision to leave Scripps. Certainly the pull to return home was strong. But we also know that the loyalty investigation left a permanent scar.⁶⁴ It did not help that the director's salary (directly under President Sproul's authority) during Sverdrup's tenure had diminished (allowing for inflation) at the time when Scripps faculty salaries (under Sverdrup's fiscal direction) had risen sharply.⁶⁵ When L. Lek telephoned President Sproul on the day of the resignation, the president offered a substantial salary increase. Sverdrup declined.

Back in Oslo, the family quickly settled into their Norwegian lifestyle. Anna, who had been divorced from an American Air Force lieutenant, married Steffan Hamre whose family had farmed a remote valley in Telemark for four hundred years; there Anna and Steffan ran a goat farm under very demanding conditions, and Anna's nursing degree qualified her for a busy career as a midwife. The Sverdrups acquired a "hytte" in the Telemark mountains, two hours from the nearest road. They took a comfortable apartment in central Oslo. A Buick sedan they had purchased upon their arrival in America in 1936 remained their mode of transportation. This was the sole outward expression of their American experience. They kept up with their many American friends and former students.

Munk came to the University of Oslo in the autumn of 1948 on a Guggenheim Fellowship, and the Sverdrups included him in their circle of old friends and colleagues, V. Walfrid Ekman, Helland-Hansen, and others. Munk tried to involve Sverdrup in working on a theory combining Sverdrup's interior solution (the "Sverdrup Dynamics") with Stommel's boundary solution. But Sverdrup was by now fully occupied with his new Norwegian responsibilities. He had always been impressed by Fridtjof Nansen's retirement dictum at the age of sixty: a full and sudden withdrawal from (rather than a gradual deterioration in) all scientific activities. Nansen went on to receive a Nobel Prize for peace in recognition of his service for the repatriation of prisoners of war.

For the next nine years, Sverdrup's activities shifted towards humanitarian endeavors, following Nansen's example. The directorship of the Norwegian Polar Institute occupied only a part of Sverdrup's time. The achievement he was most proud of was the reorganization of the Norwegian university system, away from the autocratic "Herr Professor" atmosphere of the old German type toward the more relaxed American student-

faculty relationship. This involved many years of intensive study by a commission still referred to as the Sverdrup Commission.

Sverdrup resumed his earlier career activity by helping in the organization of the 1949-1952 Norwegian-British-Swedish expedition to Antarctica. He was appointed Professor of Geophysics at Oslo University, serving also as Dean of the Science Faculty and Vice-Director of the University. As chairman of the Norwegian relief program in India, he played an active personal role in modernizing traditional Indian fishing practices.

Behind the scenes, he worked with his scientific friends in the United States and the Soviet Union in an attempt to ease the Cold War tensions among scientists of the two countries.

Sverdrup knew he had a heart problem, but chose not to pamper it. He died suddenly on 21 August 1957 during a routine checkup at the doctor's office after three weeks residence at the "hytte." Referring to his shipmates, a thirty-seven year old Sverdrup, returning from seven years in the Arctic, had written "The thing I am most proud of is that we departed as friends."⁶⁶ Now, at sixty-eight, after some stormy weather, his life ended in a calm landfall, again leaving only friends.



John Giever, Harald Sverdrup, and Gottorm Jacobsen at Maudheim, Antarctica, in 1951. Norwegian Polar Institute.

■ ■ ■ Acknowledgments

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In February 1938, Sverdrup wrote Vern Knudsen about his mentor: "(Vilhelm Bjerknes) impressed upon his assistants the advantages of using a brief and pointed language. I hope I have learned something from him." Sverdrup, in turn, passed on to his student, Walter Munk, the need for brief and pointed language: "What are you trying to say?" he would ask, "And why didn't you say so?"

■ ■ ■ Footnotes

Walter Munk is Secretary of the Navy Chair in Oceanography at the Scripps Institution of Oceanography and Deborah Day is Scripps Archivist. All figures are from the S.I.O. Archives, UCSD, except as noted.

¹ Sverdrup also noted that he had learned a Chukchi dialect while overwintering with the tribal people in Siberia.

² Harald Sverdrup to Vern Knudsen, February 1, 1938. Scripps Family Papers, Accession 92-38, Box 4, folder 39, "Scripps Institution of Oceanography, 1938." SIO Archives UCSD. The matter of judging the quality of data was always foremost in Sverdrup's mind. He wrote Vern Knudsen: "I would obtain experience in performing observations and, later, on the basis of these experiences I could know the accuracy of various methods and the limits of errors which would have to be considered."

³ Robert Marc Friedman, "The Expeditions of Harald Ulrik Sverdrup: Contexts for Shaping an Ocean Science." La Jolla, California: Scripps Institution of Oceanography, University of California, William E. and Mary B. Ritter Memorial Fellowship Lecture, 1994, page 4. This 1992 lecture was reprinted by Umeå Universitet Centrum för regionalvetenskap as Reprint No. 11 in 1996.

⁴ Sverdrup Autobiographical Sketch, April 11, 1936. SIO Office of the Director (Sverdrup) Records, Box 1, folder 1.

⁵ Ibid, p.17.

⁶ H.U. Sverdrup to Vernon Knudsen, February 1, 1938, page 2. See also Henry Bryant Bigelow, *Memories of a Long and Active Life*. Cambridge, MA: The Cosmos Press, 1964, p.31.

⁷ Sverdrup wrote Vaughan on April 11, 1936 that he wanted to help make Scripps a center for dynamic oceanography. SIO Office of the Director (Sverdrup) Records, Box 1, folder 8.

⁸ Sverdrup to Sproul, August 31, 1936. SIO Office of the Director (Sverdrup) Records, Box 1, folder 8.

⁹ In his autobiography, "Oceanographic Medley," Martin Johnson recalls that Vaughan called a staff meeting to announce Sverdrup's appointment. "Although the staff had not been consulted beforehand, no voices were raised in either objection or approval. Personally, I had a feeling of both surprise and elation..." Martin Johnson Papers, Box 2.

¹⁰ W. E. Allen, "The Growth of a Marine Observatory." *Internationale revue der Gesamten Hydrobiologie und Hydrographie* 39 (1939), 464-471. Vaughan disliked Allen's characterization of SIO as a marine observatory.

- ¹¹ Allen to Wesley Coe, March 31, 1936, Allen Papers, Box 1, folder 19. W. E. Allen wrote Wesley R. Coe, May 25, 1937 "Our new Director is just as agreeable as the other was otherwise and I think you would find working conditions here much more pleasant than formerly." W. E. Allen Papers, Box 1, folder 46.
- ¹² Allen to Coe, August 16, 1936, *ibid.*
- ¹³ "Other Business," Minutes of the September 22, 1936, staff meeting, SIO Subject Files, Box 23, folder 34.
- ¹⁴ Its hull was salvaged and refitted as a garbage scow.
- ¹⁵ Helland-Hansen memorandum, November 18, 1935, in Scripps Family Papers, 92-38, Box 3, folder 37.
- ¹⁶ Robert Paine Scripps to Curtis Hillyer, March 26, 1937. Scripps Family Papers, Box 3, folder 38, SIO Archives, UCSD.
- ¹⁷ MLR began as the Scripps arm of the California Cooperative Oceanic Fisheries Investigations. Its early history is recounted in: Harry N. Scheiber, "California Marine Research and the Founding of Modern Fisheries Oceanography: CalCOFI's Early Years, 1947-1964." California Cooperative Oceanic Fisheries Investigations Reports, 31 (October 1990), 63-83.
- ¹⁸ Eric Mills, "Useful in many capacities, an early career in American physical oceanography," *Historical Studies in the Physical and Biological Sciences* 20 (1990), no. 2: 265-311.
- ¹⁹ Gorczynski, Director of the Polish Meteorological Service, was in New York at a meteorological meeting when Poland was invaded. Reichelderfer and Brooks appealed to Sverdrup to give him a research associate appointment at SIO, and Gorczynski arrived at La Jolla on November 17, 1939. Michael Le Huquet was employed in 1940 to do some drawings for Gorczynski. Gorczynski's research assistantship was not renewed in 1941. SIO Biographical Files, Box 7, folder 232, SIO Archives, UCSD.
- ²⁰ Claude E. ZoBell, *Biological Research at the Scripps Institution of Oceanography. Collecting Net*, XI, no. 5 (August 1, 1936): 1.
- ²¹ Claude ZoBell wrote Karl Meyer, September 17, 1936: "They have piled plenty of extra work and responsibility upon me during the last three months but I think it will be easier now. Incidentally you will be interested to hear that Dr. Sverdrup, our new director, has already convinced the staff members that he is a man of vision far beyond their fondest expectation, and he is a real leader of men." SIO Biographical Files, Box 21, folder 626.
- ²² Fox to Sverdrup, September 24, 1936. Denis Fox Papers, Box 4, folder 39.

- ²³ Sverdrup to Bjørn Helland-Hansen, 2/3 January 1938, quoted in: Robert Marc Friedman, "Polar dreams and California sardines: Harald Ulrik Sverdrup and the study of ocean circulation prior to World War II." In: Margaret Deacon, Tony Rice and Colin Sommerhayes, eds. *Understanding the Oceans: A century of ocean exploration*. London and New York: UCL Press, 2001, 168.
- ²⁴ Sverdrup, "The Place of Physical Oceanography in Oceanographic Research." *Journal of Marine Research* 14, no. 4 (1955), 288.
- ²⁵ Sverdrup to Vaughan, April 20, 1945, in Thomas Wayland Vaughan Papers, Smithsonian Institution, Box 109.
- ²⁶ Deborah Day, "Bergen West: Or How Four Scandinavian Geophysicists Found a Home in the New World." *Historisch-Meereskundliches Jahrbuch* 6 (2000), 74.
- ²⁷ See for instance the reactions of SIO faculty reflected in minutes of the September 22, 1936 staff meeting. SIO Subject Files, Box 23, folder 34.
- ²⁸ U.S. National Research Council. Committee on Physics of the Earth. *Physics of the Earth*. Washington: Published by the National Research Council of the National Academy of Sciences, 1931-33; New York, McGraw-Hill, 1939-42. Volume 5, *Oceanography*, was written by a committee of American scientists and published in 1932.
- ²⁹ The original letter is in a scrapbook in the SIO Archives, Manuscript and Papers Regarding *The Oceans, 1937-1944*, accession 81-123, volume 1.
- ³⁰ Helen Raitt, noted on an interview with Ruth Ragan, 1965. SIO Subject Files, Box 13, folder 434.
- ³¹ Martin Johnson recalls in his autobiography, "Oceanographic Medley," that the reform of the Scripps curriculum and the writing of *The Oceans* were closely connected. "Lack of an integrated text in oceanography was a serious handicap. This led Dr. Sverdrup, Dr. Fleming, and me to write such a text after having abandoned an earlier idea of preparing only a syllabus for class use." Martin Johnson Papers, Box 2.
- ³² An entire journal issue was devoted to the 50th anniversary of the publication of this book, *Oceanography* 5 (1993): 155-157. The book continues to sell. Anna Sverdrup Hamre recently received her 2001 royalty check for twenty dollars.
- ³³ G.A. Morriss to H.U. Sverdrup, March 2, 1943. Scrapbook, Manuscript and Papers Relating to *The Oceans, 1937-1944*, accession 81-123, volume 4, SIO Archives, UCSD.

³⁴ J.N. Carruthers. *Quarterly Journal of the Royal Meteorological Society* 70 (1944): 159-160.

³⁵ Leif's emigration to the United States in 1914 was precipitated by a quarrel with his father. He was naturalized in 1918 and served in the U.S. Army with distinction in two world wars. The close relationship between Leif and Harald Sverdrup is never mentioned in the loyalty investigation.

³⁶ Sverdrup to Sproul, May 1, 1940, Records of the SIO Office of the Director (Sverdrup), Box 1, folder 16, SIO Archives, UCSD.

³⁷ Gas rationing and tire conservation measures were in place and Martin Johnson, among others, had to give up teaching courses at UCLA.

³⁸ See W. Munk and D. Day, "Harald U. Sverdrup and the War Years," *Oceanography*, vol 15, No. 4, 2002, for a detailed discussion (cited later as Munk and Day, 2002).

³⁹ At the same time, Instructor-Commander C. T. Suthon of the British Naval Meteorological Service was preparing some rules of thumb for wave prediction. The two groups did not learn about each other's efforts until the planning for the Normandy landings was underway (see Operation OVERLORD).

⁴⁰ This problem had received attention at the highest quarters. President Roosevelt had signaled Churchill that bad surf on the Atlantic beaches was a calculated risk. Charles C. Bates and John F. Fuller, *America's Weather Warriors*. College Station: Texas A&M University Press, 1986, 70.

⁴¹ Sverdrup and Munk tried desperately to verify the forecasting rules against observations in the operational area, using wave records in the Azores in support of Pan American Airways seaplane landings. In the process of hindcasting for the Azores sites they noted that occasional high wave conditions were not properly predicted. The wave 'spikes' occurred at regular intervals, and, as it turned out, invariably on Saturday nights.

⁴² Munk and Day, 2002.

⁴³ Sverre Pettersen. *Weathering the Storm: Sverre Pettersen, the D-day forecast, and the rise of modern meteorology*, edited by James Rodger Fleming. Boston: American Meteorological Society, 2001, p. 194.

⁴⁴ *Ibid.* pp. 216-217.

⁴⁵ Sverdrup and Munk, "Empirical and theoretical relation between wind, sea and swell," *Transactions of the American Geophysical Union*, 27 (1946): 823-827, and "Theoretical and empirical relation in forecasting breakers and surf," 27 (1946): 828-836.

⁴⁶ Blair Kinsman, *Wind Waves: Their Generation and Propagation on the Ocean Surface*. Prentice Hall, 1965, p. 321.

⁴⁷ Sverdrup, "Memorandum on post-war research of interest to the U.S. Navy with Special Emphasis on the Participation of Scripps Institution of Oceanography, University of California." SIO Office of the Director (Sverdrup) Box 1, folder 49.

⁴⁸ Revelle to Murrough P. O'Brien, November 7, 1947, in Roger Revelle Papers, MC 6, Box 1, folder 10.

⁴⁹ *Ibid.* page 3.

⁵⁰ Hubbs took it upon himself to write to biologists Henry B. Bigelow and Daniel Merriam virtually offering them the directorship in 1947 and Francis Shepard interviewed geophysicist Sir Edward Bullard. See Carl Leavitt Hubbs Papers, Box 33, folder 44, SIO Archives, UCSD.

⁵¹ Denis L. Fox *et al.* to Robert Gordon Sproul, June 15, 1947. Denis Fox Papers, Box 2, folder 61. The straw poll was taken at a meeting held off campus on Sunday, 15 June, which was attended by Fox, Hubbs, Martin Johnson, McEwen, Rakestraw, Marston Sargent, Shepard and ZoBell.

⁵² Hubbs to Knudsen, October 16, 1947. Hubbs Papers, Box 33, folder 45.

⁵³ Hubbs *et. al* to Robert Gordon Sproul, September 24, 1947. Hubbs Papers, Box 33, folder 44.

⁵⁴ Revelle to Hubbs, October 10, 1947, Hubbs Papers, Box 33, folder 45.

⁵⁵ H.U. Sverdrup, "Wind-driven currents in a baroclinic ocean; with application to the equatorial currents of the eastern Pacific." *Proceedings of the National Academy of Sciences* 33 (1947): 318-336. Some of the underlying observations are discussed in the dissertation of Sverdrup's student Robert Reid in R. Reid, "A model of the vertical structure of mass in equatorial wind-driven currents of a baroclinic ocean." *Journal of Marine Research* 7 (1948): 74-99: 304-312.

⁵⁶ Henry Stommel, "The westward intensification of wind-driven ocean currents." *Transactions of the American Geophysical Union* 29 (1948): 202-206. "My first idea was to use relaxation methods...It was Phil (Shafer) who suggested I try an analytical solution..." Henry Stommel, *Collected Works*, volume I, pages I-18 to I-23. Nelson Hogg and R.X. Huang, eds., *The American Meteorological Society*, Boston.

⁵⁷ Walter Munk, "On the wind-driven ocean circulation." *Journal of Meteorology*, 7 (2), 79-93, 1950.

⁵⁸ F.R. Bretherton, R.E. Davis and C. Faundry. "A Technique for objective analysis and design of oceanographic instruments applied to MODE-73." *Deep-Sea Research* 23 (1976): 559-582.

⁵⁹ Harald U. Sverdrup, "Brief Address in Connection with Charter Day Celebration, 1947," page 5, SIO Office of the Director (Sverdrup), Box 1, folder 4.

⁶⁰ The memorandum is dated February 5, 1947. Denis Fox Papers, Box 2, folder 61.

⁶¹ Robert Marc Friedman, *The Expeditions of Harald Ulrik Sverdrup: Contexts for Shaping an Ocean Science*. La Jolla: Scripps Institution of Oceanography, UCSD, William E. and Mary B. Ritter Memorial Fellowship, pp. 38-39.

⁶² Harald U. Sverdrup, "Informal Autobiography," February 6, 1948, SIO Office of the Director (Sverdrup), Box 1, folder 1.

⁶³ Harald U. Sverdrup to Robert G. Sproul, 1 May 1940, SIO Office of the Director (Sverdrup), Box 1, folder 16.

⁶⁴ Harald Sverdrup's American cousin George Sverdrup wrote Deborah Day, 9 October 1993 "Harald was very upset at not being given security clearance during the war. He felt he had much to contribute..." Sverdrup Family Papers, SIO Archives.

⁶⁵ The director's salary (in 1997 dollars) went from \$81,500 in 1937 to \$79,500 in 1947. For comparison, ZoBell's salary went from \$34,000 to \$53,000. All Salaries are adjusted for inflation (relative to 1997) by a factor 11.3 for 1937 and 8.03 for 1947. See *Value of a Dollar, 1860-1999*.

⁶⁶ Harald Sverdrup, "Six Years in the Arctic," SIO Office of the Director (Sverdrup), Box 1, folder 2. Sverdrup often repeated this phrase when writing about his Arctic experiences both in Norwegian and English texts.

